GNSS-based Near Real-Time Ionospheric Monitoring over Europe Available On-Line

Chevalier J.-M., Bergeot N., Brugnin C., Potliaux E., Baire O., Legrand J., Drefagne P., Aerts W.
Royal Observatory of Belgium, Av. Circulaire 3, Brussels, Belgium
www.oma.be, jean-marie.chevalier@oma.be, olsztyn@oma.be
ions@gnss.be

I. Method

1. Data

- Real-Time GPS data of 122 EUREF Permanent Network (EPN) stations (Brugnin et al., 2012) (Figure 2) provided by the RNB NTRIP broadcaster (Söhne et al., 2010)
- Ultra-Rapid Orbits from the International GNSS Service (IGS) (Beuller et al., 1995)
- Satellite Differential Code Biases (DCB) from the Ultra-Rapid Orbits from the International GNSS Service Center for Orbit Determination for Europe (CODE) (Schaer et al., 1998)

2. Estimation of the Total Electron Content from GNSS Data

- The Slant Total Electron Content (STEC) corresponds to the total number of electrons along a satellite-receiver path. It is expressed in TEC units (1TECU = 10^16 electrons.m^-2). The STEC is estimated each 30s for each satellite/receiver pair using a geometry-free linear combination (Bergeot et al., 2003).

$$STEC = \frac{r_1^2 r_2^2}{40.3 (r_1 - r_2)^2} \times \left((P_1 - P_2) - c \times (DCB_1 + DCB_2)\right)$$

- $P_1, P_2$: Phase-smoothed code observations (m) at the two GNSS frequencies $f_{1,2}$
- $c$: Speed of light
- $DCB_1, DCB_2$: Satellite DCB

- The STEC is then projected as a Vertical TEC (VTEC) at the Center for Orbit Determination for Europe (CODE) (Schaer et al., 1998)

3. Data Cleaning, Filtering and Spline Interpolation

- Medians of VTEC along each satellite track are estimated, avoiding outliers and improving the distribution of the set of data.
- The spline interpolation is iterated with different degrees of smoothing, in order to perform outlier rejection (see Figure 4).
- VTEC grid: 0.5 x 0.5° - 15 min
- Number of VTEC at IPP per map: 1692 ± 271
- Time-independent maps

II. Ionospheric Products Available On-Line

1. Interactive Ionospheric VTEC Maps (Figure 6)

- Animated ionospheric VTEC maps (movie) for a requested period
- Display VTEC value at a given point and time

II.b. Ionospheric Products Available On-Line

1) Interactive Ionospheric VTEC Maps (Figure 6)

- Animated ionospheric VTEC maps (movie) for a requested period
- Display VTEC value at a given point and time

2) Comparison statistics of VTEC maps: Comparison of VTEC maps at a given time w.r.t. the median of the 15 previous days (prediction model) highlighting the ionospheric activity. (Figure 7).

3) Ionospheric Events:

- Ionospheric events are reported into dedicated web pages
- VTEC time series of 2 days before and after the event at 3 locations in Europe, in comparison with the VTEC median w.r.t. the 15 previous days and the International Reference Ionosphere (IRI) 2012 model (Bilotta et al., 2008) (Figure 8).

III. Comparison with Global Ionospheric Maps and Climatological Model

To test the robustness of our ROB Near-Real-Time ionospheric maps, we compared them with GNSS-based CODE final IRI (latency of 5 days) (Schaer et al., 1998) during an ionospheric quiet day (18/01/2012) and during a disturbed day (22/01/2012) due to a Solar Coronal Mass Ejection impact.

1. ROB maps are not biased 0.0 ± 1.1TECU (Figure 10) w.r.t. CODE products apart during ionospheric disturbed period (absolute bias of 2.4 ± 2.0 TECu) (Figure 9).

2. ROB maps are less smooth, fitting closer to the GNSS observations (Figure 9).

3. ROB maps are not biased 0.0 ± 1.1TECU (Figure 10) w.r.t. IRI maps.

Conclusion

- The ROB Near-Real-Time Ionospheric VTEC Maps of ROB with a resolution of 0.5° x 0.5° are available every 15 minutes with a latency of 5-7 minutes at web page: www.gnss.be/Atmospheric_Maps/ionospheric_mops.php.
- Additional web pages show the ionospheric activity w.r.t. the 15 previous days and ionospheric disturbed events since January 2012.
- The ROB VTEC maps allow any user within the geographical scope of the maps to estimate near real time the ionospheric delay induced along the signal of any observed satellite.
- The ROB VTEC maps demonstrate a good agreement with Final Global Ionospheric Maps of CODE.

New products will be developed to satisfy both ionospheric and GNSS communities.

References